A Novel Technique For Characterizing The Thickness Of First-Year Sea Ice With The GPS Reflected Signal

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We have examined the characteristics of the GPS signal reflected off the sea ice surface and collected by an airborne or spaceborne receiver, forming a bistatic radar. The constellation of existing transmitters allows gathering bistatic reflections off the sea ice surface at different incidence angles over the course of a day, in contrast to a traditional radar that measures backscattering. We expect to see a strong coherent signal which is much higher than the incoherent one because of forward reflections from very smooth (particularly at L-band) and highly saline first year ice. This conclusion is supported by observations of a significant occurrence of high level, coherent scattering detected with conventional altimeters for first year ice. Hence, we focused our investigation on identifying characteristics of ice over a broad range of incidence angles that are unique to a certain thickness, as a means of measuring it. Additionally, the measurement of phase of the complex reflection coefficient at the interface between ice and air, is also possible.

We model the ice as a medium with variable dielectric constant as a function of thickness, according to realistic values of profiles of salinity versus depth for first year sea ice found in the literature. A layer of snow can also be accounted for. We calculate the power and the phase of the received coherent signal at horizontal, vertical, left-hand circular and right-hand circular polarizations. We account for variability of the ice thickness by considering a statistical average over a range of thicknesses with generalized Rayleigh distribution, as proposed in the literature. The population size is chosen consistently with the assumption of an airborne experiment at speeds of order 100 m/sec, where the samples are incoherently averaged over times of order 1 minute. For comparison, we also calculated the same quantities for a homogeneous ice layer, and for a fixed thickness.

We find that the best detector of ice thickness is the phase, particularly the difference between two components, say horizontal – vertical. This difference changes according to mean ice thickness, so that a unique correspondence can be established between thickness and phase difference over a given range of incidence angles. By contrast, the received power components exhibit a behavior less dependent on ice thickness, when averaged statistically. On the other hand, when considering a single thickness layer, the received power has clear peaks and nulls resulting from constructive and destructive interference inside the slab whose occurrence versus angle of incidence is dependent on thickness. Unfortunately, this feature cannot be use as a detector because it is not conserved when a statistical average is formed, as required in a realistic measurement.